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was his selection, by the French ministry of public instruction, as exchange professor at the Sorbonne for the year 1912–13. The official letter announcing this selection arrived in this country within a very few days after Professor Rotch's death.

He was a pioneer in a new science; an investigator, whose name is known wherever meteorological work is done; a loyal teacher who served without salary; a generous benefactor, who left to the university an enduring monument of his enthusiasm and untiring devotion to the science which he himself did so much to advance. His life and labor have been an inspiration to his scientific colleagues everywhere, but especially to those who were most closely associated with him in the work of his observatory, and in the department of the university of whose staff he was a valued member.

Robert De C. Ward.

CHARLES ROBERT SANGER

The most important achievement of Charles Robert Sanger grew out of an incident, which occurs in the life of almost every young chemist. While he was Assistant in Chemistry at Harvard College, Professor H. B. Hill was consulted by a literary colleague in regard to a number of cases of obscure poisoning in his family. At first he suggested that they might be due to carbonic oxide from the furnace and referred the question for investigation to Sanger, who found however that the air of the house was free from carbonic oxide, and therefore turned his attention to the other surroundings of the family, when it appeared the wall papers were heavily charged with arsenic, and, after these had been removed, the unpleasant symptoms gradually disappeared. In this way Sanger's attention was called to the relation of arsenic to common life, but instead of contenting himself with the study of this particular case, as most men would have done, he took up the general subject, made this field of research especially his own, and produced in it his most important additions to the science.

In attacking the subject he determined, with characteristic love of truth, to place it on a secure experimental foundation by looking for arsenic in the excreta of people suffering from the disorders commonly attributed to poison from wall papers. Before doing this however it was necessary to improve the methods of testing for arsenic, so that the quantity of poison could be detected with accuracy, even when it was present in very minute amounts. Owing to its frequent use in criminal cases very delicate tests for arsenic had been already worked out, but these showed only its presence or absence, not how much existed in the object tested; for further development therefore Sanger adopted the best of these — the Berzelius-Marsh test— in which the arsenic was detected by a stain (mirror) on a capillary tube; and his improvement consisted in producing all mirrors under identical conditions, when by comparing that from the object under examination with a set made from known weights of arsenic the quantity could be determined with surprising accuracy. Armed with this delicate quantitative method he studied the amount of arsenic in the excreta of persons living in arsenical surroundings, and found that this depended on the amount of exposure to the wall papers, curtains, carpets, or other sources of the poison. In one case even the quantity of arsenic obtained from one patient was half as great as that obtained from another exposed to the same conditions twice as long each day. Further, when the sources of the poison were removed, the arsenic gradually disappeared from the excreta at the same rate as the morbid symptoms vanished.

He was now ready to take part in the battle raging between the two camps, into which chemists at that time were divided, one maintaining that the connection between the morbid disturbances and an arsenical environment was proved, the other with equal vigor asserting that it was not. The frequent discussions of the question up to this time had consisted of a lively fusillade of assumptions and theories from both sides, which like a sham fight with blank cartridges had little result except noise. Sanger's thoroughly established facts therefore, thrown into this wordy warfare like a volley of shot, swept opposition from the field and converted to his views all, not too prejudiced to be open to conviction.

This establishment of the connection between these obscure diseases and arsenic was a service of great importance to the world as well as to chemistry, since it gave the physician a means of secure diagnosis and a certain cure for them; and further his results were used in an important study of the general relation between nervous disorders and chronic poisoning with small quantities of various agents.

It will be of interest next to consider how he had been fitted for this triumph by inheritance and training. His taste for study came directly from a line of scholarly ancestors, graduates of Harvard

College — his great grandfather Zedekiah Sanger, minister at Duxbury and South Bridgewater, Ralph Sanger his grandfather, the last town minister of Dover, so eminent that he was remembered last year by a celebration of the one hundredth anniversary of his ordination, and in the generation immediately preceding him from his father George Partridge Sanger who was judge of the court of common pleas and later United States District Attorney for Massachusetts, and from an aunt, who kept a successful girls' school in Boston, so that on this side he inherited with these scholarly instincts a love of truth and the judicial faculty for weighing evidence. On the other hand he undoubtedly owed his accuracy, his executive ability, his power of discipline, and the neat orderliness so characteristic of him to the family of Portsmouth sea captains from which he was descended through his mother, Elizabeth Sherburne (Thompson) Sanger; while from both sides he drew that faithfulness, which was his most prominent characteristic.

It was to be expected from this family history that he should choose the life of a student, but it is strange that he turned to chemistry rather than to some branch of literary work. Perhaps the practical ability inherited from his mother's ancestors gave this direction to his energies. However this may be, the call of science to him was irresistible, and even when he entered Harvard College, his taste for chemistry was strongly developed. I remember well the marked impression he produced on me in his first chemical recitation, and throughout his course he was an eminent student in that subject, which occupied a large part of his time.

On graduating in 1881 he began the higher study of chemistry, and for the first time came into intimate relations with Professor H. B. Hill, who was to have such a determining influence on his life; for, although he passed the second year after his graduation (1882–1883) in Europe studying at Munich, and at Bonn, where Professor Anschütz, struck by his ability, devoted special attention to him, and thus became an important factor in his higher education, Hill was his chemical father. During four of the five years, when he was growing into a chemist, he shared Professor Hill's private laboratory, working the entire day in his company, and part of the time in the even closer intercourse of a common research. Upon Hill therefore he modelled his methods of research, and views of chemistry, and this was the easier, since the two men naturally resembled each other as closely as father and son in aims, mental habits, and ideals. This warm and beautiful friendship was broken only by the death of the older man.

His work for the Ph. D. consisted of an investigation of substituted pyromucic acids, but the research on arsenic, already described, soon removed him from this field of pure organic chemistry cultivated so successfully by his master. Continuing study in his chosen line, after he had proved the reality of arsenical poisoning from wall papers, he attacked a puzzling mystery, which had baffled all attempts to penetrate it, but with this he proved less fortunate. The symptoms of wall paper poison are divided into two classes, one consisting of irritations of the mucous membrane obviously produced by arsenical dust, the other appearing in far reaching disturbances of the nervous system. Disorders of this latter class have been observed, when poisonous dust was nearly excluded, since the arsenic was contained in a glazed paper, or even, when its formation was impossible, because the arsenical paper was covered by one or more free from arsenic, so that in these cases the poisoning could have been due only to a gas; but here was the mystery—all attempts to detect an arsenical gas had failed (with two exceptions) whether in rooms with poisonous wall papers, or in mixtures of arsenic with organic matter, which should be even more efficient. During the earlier theoretical stage of the discussion those contending against the arsenical source of the nervous disorders were fond of arguing, that if arsenical they could be due to a gas only, as this gas could not be detected, it did not exist, and therefore the symptoms were not caused by arsenic. I think this is a fair statement of this argument, which in spite of its want of logic carried much weight, until Sanger destroyed it, by his discovery of arsenic in the excreta. But, although he proved in this way the existence of an arsenical gas, the puzzle still remained, as to what the gas was, how it was formed, and why it escaped detection. To the study of this problem he devoted a great deal of time, but, as he followed the methods of his predecessors, he was no more successful than they, and in spite of the most careful work did not succeed in detecting a trace of an arsenical gas. The truth was a new line of attack was needed, and this came from cryptogamic botany instead of chemistry, when Gosio announced his discovery that an evil-smelling gas containing arsenic was given off by three sorts of moulds growing in contact with arsenic and organic matter. Sanger at once repeated Gosio's experiments with the only one of these moulds accessible to him (*mucor mucedo*), but without success. Later however with a specimen of the most efficient sort (*penicillium brevicaule*) sent him by Gosio he succeeded in confirming the Italian's results. This important confirmation of the efficiency of moulds in the production of an arsenical gas was his last contribution to the study of poisoning from wall papers, because he felt obliged to retire from the field in order not to interfere with Gosio. This was certainly unfortunate, since his earlier work justifies the conviction that he would have solved this problem also, if he had not been compelled to relinquish the study of it. As it is, the mystery remains; Biginelli has found, it is true, that the gas formed by the moulds is an arsine, a substance related to the alkaloids and therefore probably more poisonous than most other compounds of arsenic, but it has not been shown how this, or any other gas can be formed from wall papers, which only in exceptional cases are in situations moist enough to favor the growth of moulds.

When in this way Sanger was shut out from the practical side of this investigation, he turned his attention to the purely chemical side of the work, extending his analytical method to the quantitative determination of antimony; and later applying this system of determining the amounts of arsenic, or antimony to the method of Guthzeit, which in his hands became the most accurate and delicate method known for such work, and even displaced his own earlier Berzelius-Marsh process, admirable as that was. I think he considered this the best piece of work that he did, but I must give the preference to his work on arsenical poisoning from wall papers on account of its great practical importance, and because in this connection he worked out the general principle at the bottom of all these methods.

Two important papers, which occupied the last years of his life, belong to a different line of work. His object here was to prepare the silicon compound corresponding to phosgene; a well known derivative of carbon; but a reaction, which should have led to it in view of the strong resemblance between these elements, gave different products, the identification of which, simple as it seems at first sight, required an unusual amount of ingenuity, chemical insight, and skill in manipulation. This research brought out the entirely unexpected fact, that our knowledge of pyrosulphurylchloride and chlorsulphonic acid — two compounds supposed to be thoroughly established — rested on an inadequate experimental foundation, and in the first of these papers accordingly he placed them on a secure basis with his usual faithful accuracy. The skill in devising apparatus, and overcoming obstacles shown in these papers adds to our regret, that he was not spared to carry on other researches in this somewhat neglected field of inorganic preparations.

Among the work he left unfinished was a much needed method for the quantitative determination of small amounts of fluorine, a beautiful application of the general principle, that had proved so useful in his work on arsenic. It is hoped that this (and some other papers) can be brought into a state fit for publication, and, although shortly before his death he told me it was far from ready, I feel sure that even then it had been tested as carefully, as most chemists think necessary for their work; and this leads me to speak of Sanger's most marked characteristic, admirable in itself, but developed to such an extent, that it reduced the amount of his work very materially. This was an accuracy and care truly phenomenal. Most chemists are satisfied, when they have followed the work of their students closely, and tested it at certain commanding points. A few think it necessary to repeat all the work of their students, of these Hill was one, and in this single respect I must feel his influence was unfortunate, as his precept and example developed this side of Sanger's character to such an excess, that he was never willing to publish, until he had repeated the work of his students not once but many times. This is the principal reason why the list of his papers is short, and does no justice to the amount of work he did, or to his chemical ability; but on the other hand the wonderful accuracy of every published statement of his gives his work unusual authority. Other reasons for the comparatively small number of his papers are, that much of his time was taken up by work in industrial chemistry, which could not be published, and still more the almost over-faithful performance of his duties as teacher and Director of the Laboratory. In this last capacity he was always ready to sacrifice at the expense of his own investigations unlimited time for the purpose of advancing the researches of his colleagues by providing special apparatus, or material for them.

Apart from his chemical work Sanger's life, like those of most scientific men, was barren in striking events. He was born in Boston, August 31, 1860, but early in his boyhood his father moved to Cambridge, where he was fitted for college at the High School. He soon became an important member of the Class of 1881 at Harvard, partly because of his prominence in the societies, and as a member of his class nine, still more because his warm affectionate nature endeared him to his classmates, and enriched him with many lasting friendships. In his senior year he was elected Class Secretary — the important permanent officer of the class — and he met the duties of this office with the same enthusiasm he showed in his chemical work, while his characteristic methodical thoroughness and devotion made his work a model for all class secretaries.

His first year after graduation was passed in study for the degree of Master of Arts with Professor Hill, to whom he returned after his year (1882–1883) in Europe. He took his degree of Doctor of Philosophy in 1884, after which he served as Assistant in Chemistry in Harvard College, until in 1886 he was appointed Professor of Chemistry at the United States Naval Academy at Annapolis, a post for which he was especially fitted by nature, or perhaps rather by inheritance. In 1892 he accepted the better position of Eliot Professor of Chemistry at the Washington University of St. Louis.

In 1899 Professor Hill found the duties of Director of the Chemical Laboratory of Harvard College so exacting, that he was forced to give up the large elective in qualitative analysis (Chemistry 3) which he had taught for many years. We considered this course, as developed by him, our most precious treasure, since it trained men in observation and inductive reasoning better than any other known to us, but on the other hand, if improperly taught, it would sink to a mechanical routine worthless for educational purposes. It became therefore a matter of grave anxiety with us to find a successor for Professor Hill in this course, who should be able to carry it on worthily; and after a careful search of the whole field we decided that Sanger was by far the best man, and accordingly he was called to Harvard University as Assistant Professor of Chemistry in 1899; and in keeping the work in qualitative analysis on its previous high level he more than justified our faith in him.

As a teacher he was somewhat austere; all his students were expected to live fully up to his own standard, and he always retained some touch of the naval discipline. In particular research with him was no easy matter — the same accuracy, the same thoroughness, the same limitless patience, that he showed in his own work, he demanded of his students, but, as they saw he required nothing from them, which he did not exact from himself in even greater measure, they worked with enthusiasm, and felt for him an affection perhaps even deeper and stronger, than would have been inspired by an easier teacher.

An additional reason for his appointment at Cambridge had been that he was excellently fitted to act as director of the laboratory, should this become necessary. The death of Professor Hill in 1903 brought this necessity only too soon, and led to his appointment as Director, and promotion to a full professorship. I have already dwelt on the self-sacrificing devotion shown by him in this position. In all other respects too he proved an ideal choice, wise, and prudent in planning the work, methodical, thorough, and efficient in doing it.

At first it was hoped that he would take charge of the teaching of industrial chemistry in Harvard University; and in 1902 he went abroad for the summer semestre to fit himself better for this work. There he studied at Dresden with Professor Hempel, but with little result beyond a very pleasant and long continued friendship, for it was found that the great labor involved in the directorship rendered it impossible for anyone to give more than a single course in addition, and in his case this could be no other than qualitative analysis. He was not convinced of this impossibility however, until for several years he had made a gallant effort to carry the industrial chemistry on his already overburdened shoulders.

His uncommon administrative ability made him very useful on committees, especially in the Administrative Board of the Lawrence Scientific School, of which he was one of the pillars, but this also robbed him of much time, which would otherwise have been devoted to research.

The care and thoroughness shown in his work appeared also in his amusements, and made him an unusually skilful photographer and successful gardener.

On December 21, 1886 he married Almira Starkweather Horswell, who died January 6, 1905, leaving three children, Mary (married to H. A. Bellows), Eleanor Sherburne and Richard. On May 2, 1910 he married Eleanor Whitney Davis, the daughter of Andrew Mc Farland Davis, who survives him.

He was a member of the German Chemical Society, the Society for Chemical Industry, and the American Chemical Society (Vice-president of the New England Section 1902–1903). He was elected a fellow of our Academy, January 14, 1891; served on the C. M. Warren Committee from 1904, until his death; and was Chairman of the Publication Committee, that is editor of the Proceedings, from 1909 to 1910. His service in this last capacity showed his usual efficiency. Its short duration was due to the fact that he was already stricken with the disease, which led to his death, in fact the most prominent symptom of this was his nervous eagerness to add new undertakings to the load which already weighed him down, for in addition to our Proceedings he took sole charge of raising money for a new laboratory at Cambridge, and, when the American Chemical Society met in Boston and Cambridge in 1909, he was most active in arranging for its reception, and organized an interesting exhibit of the chemical activities of Harvard College. This was the finishing touch however, and at the end of that academic year he was so completely broken down that he was obliged to give up his regular work. Then followed a weary chase after health. A journey to Europe that summer did no good, nor was he more fortunate in the next winter spent on leave of absence, or in the following summer. In the autumn of 1911, although no better, he took up his teaching again, for his physicians decided that, if work were forbidden, the longing for it would do him more harm than the work itself. Accordingly he began to lecture in spite of agonizing attacks of pain, giving us the spectacle of duty triumphing over suffering, as before it had led him to disregard his own ease and advantage; but this heroism was in vain, the attacks grew more frequent, until in the middle of the year lecturing became impossible; but even then, as before, he filled up every cranny of his life with work on his papers feeling that rest was impossible, while anything remained undone, until death found him working at his post on February 25, 1912. The faithfulness, which had moulded every action of his life, reached a fitting climax in the heroic devotion to duty to its close.

C. L. Jackson.

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